from the radiant pipes.

In order to establish an accurate record of the amount of fuel burned, a separate meter was installed to measure the amount of gas burned by the infrared system. After one full year the data provided by the local gas company showed an average of 62% reduction in fuel consumption for the CO-RAY-VAC infrared system compared to unit heaters and convection tubes. At this writing, the savings has consistently been in the area of 60% after over four years of use. Additional systems have been installed to now heat 70,000 square feet of glass greenhouse space. A new area of 60,000 square feet of glass to be heated with CO-RAY-VAC is currently under construction

In addition to reduced gas consumption, it was discovered that the electrical energy required to operate the heating system was only 10% of that required to operate unit heaters and convection tube fans.

In our installation the energy savings were enough to pay the entire cost of the equipment and installation in two years. The cost of energy now has increased to the point where in 1980 the savings will be equal to the original cost and each succeeding year the amount of dollars saved will be greater. We estimate that over a ten year period, with expected energy cost increases, we will save an amount in excess of ten times the original cost.

Infrared radiant heating has now been used successfully on a wide variety of greenhouse crops. Plants grown on the floor, raised benches, hanging baskets, or even densely populated combinations of the above have all responded favorably to this even, gentle means of heating. At this time, no crops have shown adverse effects in a properly installed infrared system. One should be careful to follow factory recommendations to insure the best results. Comparing the trade-offs one must accept with other means of energy conservation now on the market, infrared offers so many advantages that it promises to be the heating system of the future.

X-RAY DETERMINATION OF HORTICULTURAL SEED QUALITY

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Abstract: X-radiography is a quick and inexpensive means of assessing soundness of the internal structure of seeds. an indirect indication of seed viability Testing of seed quality before sowing can ameliorate problems of low yield or overcrowding in the propagation of perennial ornamental plants

INTRODUCTION

Vegetative propagation techniques are the most widely used for production of perennial ornamental plants. They are the preferred and sometimes necessary routes to reliably preserve the desirable genetic characteristics of the mother plant Of various vegetative techniques, rooting of cuttings is most popular for woody cultivars. One advantage of sticking cuttings into rooting flats is that the number and distribution of plants can be accurately controlled. Overcrowding and excessive competition are avoided. Another is that propagation material can be collected without depending on seed production.

Still hundreds of kinds of perennial ornamental plants are propagated from seed; either for marketable plants or for rootstocks for grafting. Production from seed is often preferred for those kinds that can be vegetatively reproduced only with extreme difficulty, or under extraordinary conditions. A major advantage is that the cost, in time and labor, of preparing seedling flats is substantially lower than for preparing flats of cuttings.

In spite of the productivity advantage in using seed, there are some problems specific to propagation from seed. It is not rare for only a few seeds to germinate from several hundred seeded into a flat. Such events are wasteful of labor and time and of space in the propagating facility. In extreme cases, new seed must be obtained and the crop resown if quotas are to be met. Even then, a substantial amount of time may have already been lost waiting for germination.

If the new seed is of high germinability and good vigor, misfortune may strike again in the form of overly dense seedlings. Root entanglement is more severe and separating roots slows transplanting and increases injury to seedling roots. Seedlings tend to be leggy and unable to support themselves after transplanting. Late-germinating seedlings are often repressed. This results in seedlings having a large range of sizes. Control of disease is more difficult among crowded seedlings. Thinning back to a desirable density is usually not done because of added labor costs.

There is then, a problem of predicting seedling yield from a given seed lot. Many factors can influence seedling yield. Pretreatment of seed, time of sowing, level of sanitation, and environmental factors can certainly affect rate and extent of germination. But a frequent cause of poor seedling yield is simply poor seed quality. Factors that contribute to low seed quality include: absence of endosperm or embryo, embryo immaturity, genetic defects, insect infestation, seed diseases, lack of freshness, and poor storage conditions.

SEED TESTING

Germination Test. The reliability of seedling propagation can be enhanced by testing seed quality before sowing. Given some measure of seed variability, the propagator is in a position to adjust his sowing rate to result in the desired yield and density.

The most reliable test of seed viability is the germination test. Replicate samples of the seed lot are subjected to controlled conditions for a specific period of time after which the percent of germinated seed is determined. This type of test is particularly well-suited to agricultural crop seed which generally requires little or no pretreatment and germinates within a few days. The seeds of many perennial plants, however, often require weeks or months of pre-conditioning to enhance germination. Even then it may take weeks more before germination is complete. Unless the seed stores well, the lot from which the samples were drawn may significantly decline in vigor while the test is going on. This need for time and for special equipment make the conventional germination test unattractive for many ornamentals. Furthermore, the test is destructive in that the sample is consumed in testing. The 200 to 500 seeds needed for a reliable test can be a substantial portion of some ornamental seed lots.

Cut Test. There are a number of so-called quick tests that are useful in determining seed quality. The simplest of these is the cut test. Seeds are cut open and the interior examined. Those that are firm, full, and of healthy color are judged to be viable. This test can also be used to check ungerminated seed at the end of germination tests or in the seedling flats. With practice, one can learn to detect abnormalities in otherwise healthy looking seed. These might include immaturity, malformation, or inversion of the embryo.

Tetrazolium Staining. Among several biochemical staining techniques, the tetrazolium chloride, or TZ test, is the most widely used. In this test, seed is soaked in water for one or two days. The seed coats are cut or pierced to permit penetration of the test solution. A 1% aqueous solution of 2,3,5 triphenyltetrazolium chloride is the reagent. Specimen seeds are immersed in the solution and kept in the dark for 24 hours at room temperature. After rinsing, the seeds are cut lengthwise and red-staining of the tissue is evidence of viability. Variability in stain intensity sometimes makes interpretation difficult. Like the cut test, the TZ test is a destructive test and requires time-consuming handling of each seed.

Hydrogen peroxide stimulation of the germination test and culturing of excised embryos are other quick tests beyond the scope of this discussion. These, and the X-ray test to follow, are detailed in the bibliographic references.

X-ray Testing. Perhaps the most rapid of the various quick tests for seed soundness is the X-ray examination of internal seed structure. With soft X-ray, a large sample of seed can be examined. The production of an X-radiograph takes only a few minutes and the test is best performed on seed dried to normal conditions.

Another advantage is that the low radiation dose does not damage the seed. Correlative tests, such as germination or tetrazolium tests, can be performed on the same seed sample, or on selected individual seeds.

A major drawback to the X-ray test is that, like other quick tests, it does not provide a direct measure of seed viability. It does provide, for those seed for which it is suitable, an estimate of soundness or completeness of the material within the seed coat Absence of endosperm; absence, immaturity or malformation of the embryo; cracked or broken seeds; insect larvae; and shrinkage of the interior (an indication of "old" seed) are evident in the radiographs.

The equipment used for performing X-ray examination is available "off-the-shelf". The X-ray unit in our laboratory is a Hewlett-Packard "Faxitron" Model 43804N. The other major piece of equipment is a Kodak Ektamatic Model 214-K Processor for the instant paper radiographs. Sample holders, film holders, chemicals, photographic paper, radiation exposure badges, and a dark room round out the equipment and materials needed. The cost of the equipment and alternatives to direct purchase of X-ray equipment will be discussed below.

While operators must be trained in the safe use of X-ray equipment, the process for radiographic testing is quite simple. A representative sample is taken from the seed lot. In the simplest form, a known number of seeds can be distributed directly on the film holder. But to maintain individual seed identity and to simplify counting, the use of a compartmented sample holder is preferred. A Plexiglass plate, 5 mm thick, drilled with 100-15 mm diameter holes will accommodate all but very large seed. A 0.1 mm thick Mylar sheet is glued to the underside to hold the seed without significant attenuation of the X-ray beam. One seed is placed in each cavity and the sample holder is placed on the film holder which is then placed in the X-ray cabinet. The seed is exposed for a predetermined time at a selected X-ray tube potential. Exposure times are generally from ½ to 3 minutes at 15 to 20 kilovolts tube potential.

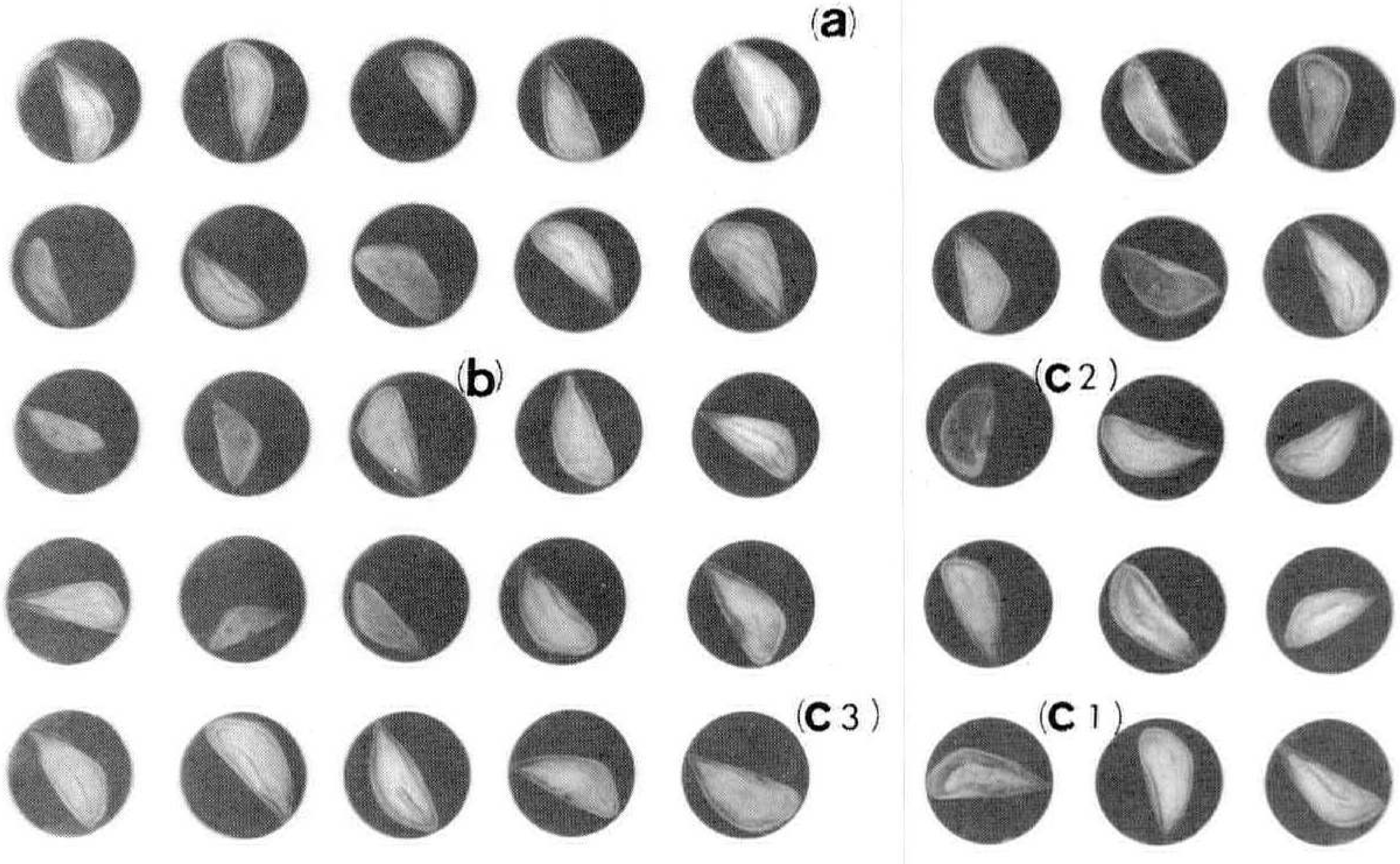

Figure 1. A portion of a radiograph of *Cedrus deodara* with examples of: (a) sound seed, (b) seed with questionable structure, and non-viable seed with shrunken endosperm (c-1), empty seed coat (c-2), and missing embryo (c-3).

Figure 2. X-radiograph of *Abies procera* seed. Seed has been segregated to illustrate empty seed (top two rows), normally filled seed with distinct embryos (center two rows), and seed infested with chalcid fly larvae (bottom rows).

The exposed paper is removed from the holder under a photographic safelight and passed through the instant processor. The radiograph can be taken immediately into room light and a count made of the sound seed in the sample The radiograph can be dried and data recorded directly on the radiograph as a permanent record.

Seeds of the family *Pinaceae* are well suited to X-ray analysis. A radiograph of the seed of *Cedrus deodara*, (Figure 1), shows examples of (a) well-filled seeds with distinct embryos, (b) questionable seeds with indistinct or distorted embryos or space between the endosperm and seed coat and (c) obviously nonviable seed with empty seed coat, shrivelled contents, and missing embryos.

Abies procera, an important forest species of the Pacific Northwest, presents a clear image of the embryo in sound seed (Figure 2). Empty seed is easily identified and chalcid larvae infestation is distinct. For clarity, these have been segregated.

Insect damage has also been observed to the seed of species of broader horticultural interest. In seed lots of *Phoenix reclinata* and *Phoenix canariensis* seed-weevil larvae were found in nearly every seed. These seeds appeared normal under ordinary light except for tiny holes along the cleft of the seed.

Embryo distortion is frequent in *Strelıtzıa nicolai* (Figure 3). It is not known if this characteristic affects viability Using the radiograph, individual seed with distorted embryos could be selected from the seed holder and subjected to tetrazolium or germination tests. This ability to perform confirmatory tests on the same seed sample exemplifies the research value of X-ray testing.

Sometimes the distinction between sound and poor seed is a matter of degree, making interpretation of the radiograph difficult. Sound seed of *Acacia latifolia* results in a strong image but shows little or no detail of the internal structure. The endosperm of obviously dead seed is shrivelled or deeply pitted. But all degrees exist between these extremes and "lethal" level is uncertain.

Some seeds have characteristics that preclude making estimates of seed soundness by X-radiographs Since the X-ray equipment available to seed analysts cannot magnify the image, seeds with dimensions less than about two millimeters are too small to produce meaningful detail The pericarp or seed covering of some seed is so dense or convoluted that the details of interior structure are obscured as illustrated in the radiograph of *Harpephyllum caffrum* (Figure 4). *Cycas revoluta* is an example of a seed with a large, well-developed embryo that is nearly

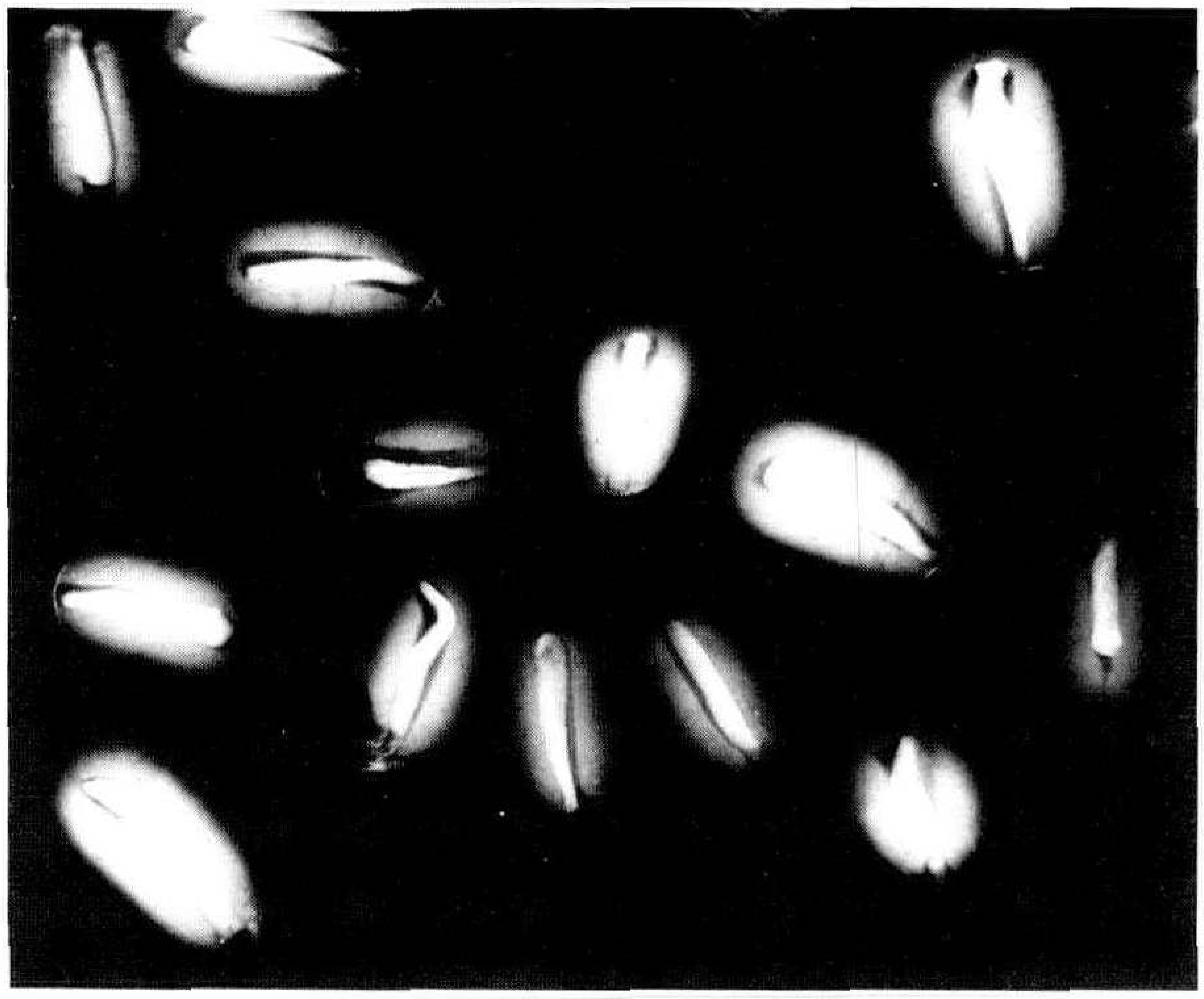

Figure 3. X-radiograph of *Strelitzia nicolai* seed. Distorted and abnormally small embryos are evident. The two seeds in the upper right center have a normal appearance.

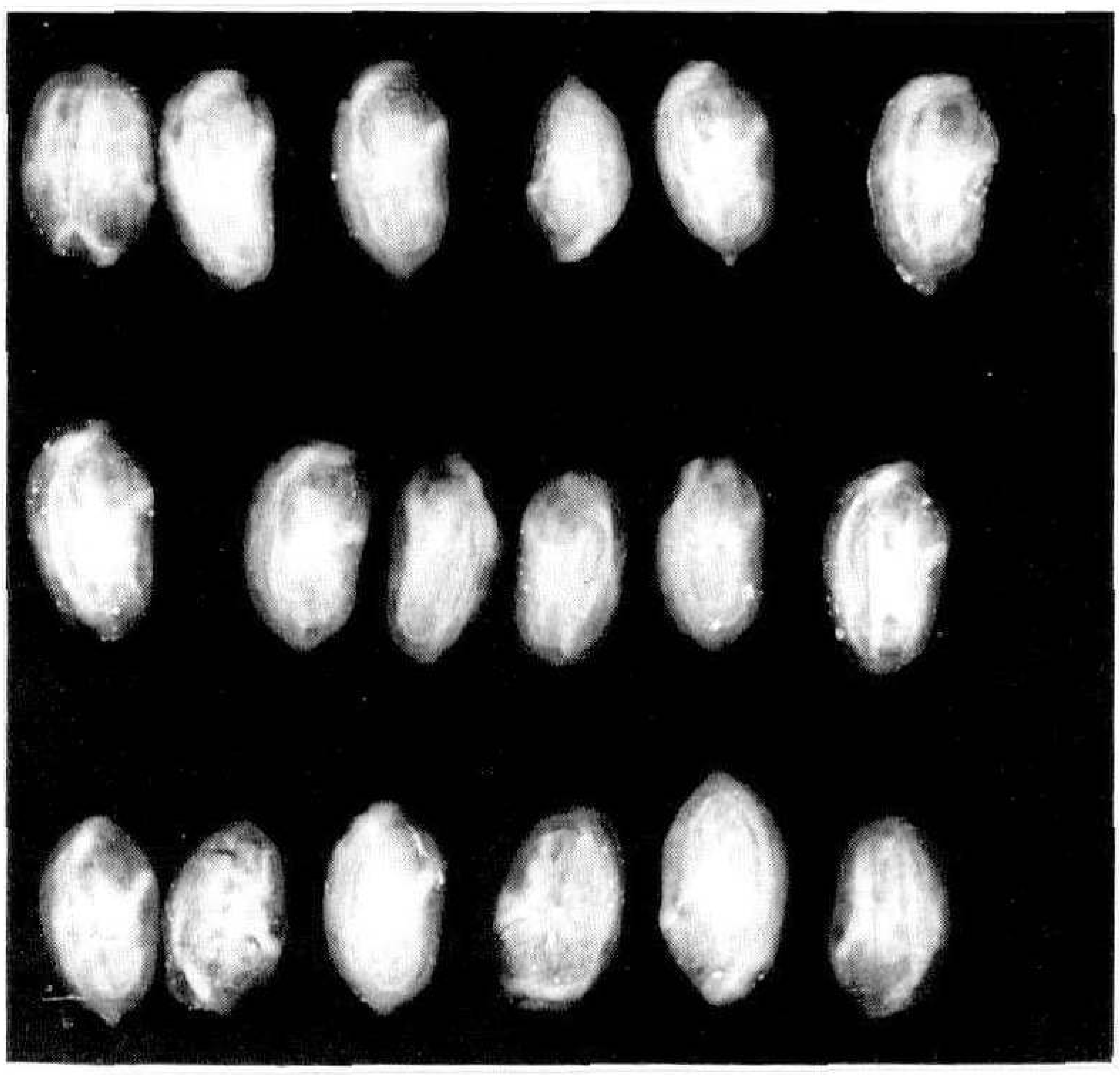

Figure 4. The thick and convoluted surface of the seed of *Harpephyllum caffrum* obscures the internal structure and diminishes the value of radiography as a quality control test.

invisible in a radiograph because of the thick, fleshy endosperm that surrounds it. *Asparagus plumosa* is a smaller scale example of this same characteristic.

Nonetheless, there are many kinds of seeds used in ornamental plant propagation that do produce clear X-radiographs. The commercial propagator might consider X-ray of seed for two reasons: First, as a quality control test for seed lots either purchased or collected from stock plants available to the propagator. If the radiograph clearly indicates poor quality the propagator may refuse to purchase or decide not to sow. Second, as an aid in producing the desired number and density of seedlings by adjusting the sowing rate in accordance with the proportion of sound seed in the radiograph.

Radiographs give only indirect indications of seed viability. Users of the X-ray technique should, in the beginning, run coincident viability tests; either germination or tetrazolium tests. Actual emergence in seedling flats should be compared with predications made on the basis of the radiographs. In this way a clear correlation between X-ray soundness and seed viability can be established for each species of interest.

To establish an X-ray testing capability would cost on the order of $10,000 Very few producers or users of horticultural seed could justify this level of investment. A relatively inexpensive alternative is to employ the services of appropriately-equipped seed testing laboratories.

While there may be others, the Oregon State Seed Testing Laboratory at Corvallis, Oregon is geographically the closest to Western nurserymen. A second is the Eastern Tree Seed Laboratory in Macon, Georgia. While neither of these two laboratories has wide experience with ornamental plants, each is well equipped and available to perform a full spectrum of seed quality tests. The few dollars spent for testing a seed lot is a small cost if it prevents sowing a large seedling crop that fails to germinate

SUMMARY

As long as seed has an important role in the propagation of ornamental plants, the propagator will be concerned with the cost and quality of seedling production. Knowledge of the quality of seed can reduce the time, space and labor required for seedling production. Several quick tests of seed quality are available The X-ray test is among the quickest and easiest to perform and provides a measure of the soundness of many seeds of horticultural interest. It is inexpensive and non-destructive to the seed. The cost of equipment generally confines performance of X-ray testing to users or producers of large quantities of seed or to

laboratories providing seed-testing services. Such laboratories are available in the Eastern and Western United States.

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MODERATOR ED SCHULTZ: We now have time for some questions for our speakers.

BRUCE BRIGGS: On heat radiation in greenhouses, how do you deal with the problem in a double poly house when you begin to accumulate snow — how do you melt the snow off?

CHARLES HOAGLAND: I think Bruce is wondering if there is any heat at the top of the poly house covered with snow. We will not have as much heat at the top of an infra-red heated house as in a unit heater system but the heat will be there. We have in Washington State many, many snowfalls, some 8 to 10 inches, and we have been able to melt the snow off the poly house with infra-red heaters.

ED SCHULTZ: You will find that the snow that accumulates on the house is an insulation material and you will get heat build-up and give you a little slight slick between the snow and the glass or the snow and the fiberglass or poly. That helps let the snow slide down if there is any slope.

VOICE: In the tissue-cultured rhododendrons, when you took the clumps to root that had callus, did you use bottom heat and mist? What were you planning to do?

BOB TICKNOR: Did we use bottom heat and mist? The answer to both is no. We were working under lights in a basement; we were not using bottom heat. We put a poly tent over them to hold the humidity in. The radiation temperature was about 80°F under the poly tent.

RALPH SHUGERT: Jay, when you take a lot of stratified seed, let's say *Taxus capitata*, which normally needs 12 months stratification, can you put the seeds under X-ray and determine from that about what stage the seed is in during the period of stratification? Is it ready to germinate, in other words?

JAY ALLISON: You could if there was some evidence of the embryo beginning to swell, for example, a root radicle just ready to emerge through the seed coat. I might add about testing of stratified seed is that if the seed is totally imbibed with water or even an empty seed coat that is filled with water, water will have about the same absorbance of X-ray as the endosperm or the embryo of the seed. Often it is found to be beneficial in X-raying seed that has been fully imbibed or stratified for a long period of time to partially dry the seed before running an X-ray test This will bring out the detail of the embryo much better.

RALPH SHUGERT: X-ray tests could well be used along with a cutting test. If I made a cutting test on *Taxus capitata* seeds, for example, that were stratified 8 months, the cutting tests might show 80 to 85% good seeds. Then if I sent the seed to a lab — and the X-ray report then came back, I would then have, conceivably, information that would allow me to plant three months earlier than I normally would.

JAY ALLISON: Yes, very definitely.

CHET BODDY: I would like to know from Bill Nelson about that bottom heat system. What is the material that the copper pipes ran through?

BILL NELSON: That was in concrete. That was in Don Dillon's propagation beds. I am not using any circulating water; mine is strictly radiation from the water that has been heated. I want to mention a book called, "Solar Living Greenhouse Digest," printed in Arizona. It describes a lot of new materials that are coming into the forefront in solar heating. One of them is the very inexpensive series of tiny pipes, tubes of polyethylene, black poly; it looks like a real way of saving money because copper is just sky high. With the success that Don reports it is probably a good investment though, but I would have tried some of these other materials. Hines Nursery, I know, has tried a number of kinds of polyvinyl chloride (PVC) pipe that did not work but they finally found one in the East where they use it for melting snow or ice on the roadway. That one was, apparently, very effective.

JOLLY BATCHELLOR: Twenty-five years ago there was a philodendron grower in the Pacific coast area who had the idea of running hot water through pipes in his propagation bed.He did that and had beautiful results except that the electrolysis ate the pipes up.

BOB TICKNOR: Several growers in the Oregon area are using hot water for their propagation bed heat source.

JOLLY BATCHELLOR: What kind of pipes are they?

BOB TICKNOR: Klupengers use galvanized pipe. John Mitsch uses some type of polyethylene. John just had a big installation put in, using a heat pump as a hot water source. He also has solar panels that go into the same storage reserve. He has a 20,000 gallon tank to hold the water and pipes go under the beds. He has a 100′ × 100′ greenhouse heated that way.

ED SCHULTZ: John is using low temperature, like 80° to 100°F or less. It may have some effect on the electrolysis, I don't know. I think he is using PVC pipe.

JIM SAHLSTROM: We use a drip tubing that is used for drip irrigation. Unfortunately, we heat with electricity, but we use a hot water heat element screwed into a 2-inch tee. We heat the water to about 80°F which goes into a manifold having about 9 pipes, and we send this down the house about 90 feet. The nice thing about plastic pipe is that it is a poor conductor of heat, but copper is a good conductor of heat; you put hot water in at one end and you get cold water at the other. But by putting hot water in at one end of this flexible plastic tubing, you have the same temperature at the other end. So we can put hot water in, pump it through the system, when it gets to the far end of the greenhouse we cross over, heat it up again, but it is already warm. Send it back to the other side of the greenhouse through the system again; it is a round-robin system. The type of tubing is flexible, and we work on benches that are right on the ground so we can step right on the tubings or run over them with our equipment. No problem with breaking or corrosion.

VOICE: Referring to Jim's statement that hot water running through a piece of copper tubing cools off by the time you get to the other end, I don't think that is because of the copper tubing; I think it is because of the design of the system. Circulating the water with a pump you could arrange to have the same temperature at both ends of the bed.

JIM SAHLSTROM: That is correct, but copper does cool off a lot faster than poly though.

ED SCHULTZ: But you could correct it by increasing the speed of the water going through.

CONIFER AND MAGNOLIA GRAFTING

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The "upright" junipers are some of the most sought after plants we grow at Monrovia Nursery. The high demand for these plants is in part maintained by the difficulty in producing them in large quantities. Although some can be successfully and economically grown from cuttings, many others must be propagated by grafting. The types of junipers we graft are mostly cultivars of *Juniperus scopulorum,* some of which are: 'Cologreen', 'Gray Gleam,' 'Welchii,' 'Tolleson's Weeping' and 'Wichita Blue.' Except for the use of different understocks, the methods for grafting our other conifers are the same as those used for the junipers. Since the grafting of our *Magnolia grandiflora* types coincides closely with that of our conifers, their production will also be described in this paper The cultivars of magnolia we are now grafting are: 'Majestic Beauty,' 'St. Mary' and a USDA introduction called 'Little Gem.'

JUNIPERS

Understock: For good results, it is important to start with a good, vigorously growing understock. There are three we commonly use: *Juniperus chinensis* 'Hetzii', *J. virginiana,* and *J. virginiana* 'Skyrocket.' We like to use 'Skyrocket' because it is less susceptible to the various fungal diseases which can infect *J. virginiana.* Also, 'Skyrocket' produces a straighter, more graftable understock than 'Hetzii.'

The 'Skyrocket' are rooted as cuttings and then are potted into liners They will be ready to graft approximately two years from the time the cutting was made. About three weeks prior to grafting we start preparing the understock. This preparation consists of: 1) sorting for size, (5 to 7 mm in diameter is desired), 2) pruning up the sides in order to clean the working area for the graft, (an area of 7 to 10 cm starting at soil level and extending upward), and 3) pruning the tops to reduce foliage and create a uniform appearance. This process is started approximately the first week of November. One week prior to grafting, the under-